REMARKS

Claims 32 and 71-131 are pending in this application By this amendment, claims 33-70 are canceled and claims 71-131 are added. No new matter is added.

Applicant would like to thank the Examiner for indicating that claim 36 contains allowable subject matter.

Claims 32, 33, 38, 39, 42-44, 46-53, 56-59, 61, 63-65 and 66-70 were rejected under 35 U.S.C. §103(a) over Mallik, U.S. Patent No. 5,128,779. Claim 32 has been amended to incorporate the allowable subject matter from claim 36 and claims 33, 38, 39, 42-44, 46-53, 56-59, 61, 63-65 and 66-70 are canceled, rendering the rejection moot.

Claims 34 and 35 were rejected under 35 U.S.C. §103(a) over Mallik and Cueli, U.S. Patent No. 5,513,019. Claims 34 and 35 have been canceled, rendering the rejection moot.

Claims 41, 45 and 55 were rejected under 35 U.S.C. §103(a) over Mallik in view of Staub et al., U.S. Patent No. 5,886,798. Claims 41, 45 and 55 are canceled, rendering the rejection moot.

Claims 60 and 62 were rejected under 35 U.S.C. §103(a) over Mallik in view of Kaule et al., U.S. Patent No. 6,294,241. Claims 60 and 62 are canceled, rendering the rejection moot.

I. New Claims 71-103

Regarding new claims 71-103, Applicant respectfully asserts that these claims are patentable for at least the following reasons.

In rejecting canceled claims 66 and 68, the Office Action stated that Mallik "does not teach explicitly that it is a volume hologram. But volume hologram is just one type of well-known hologram, which by definition has the thickness of the interference fringes recorded, is comparable to the thickness of the recording medium." The Office Action further alleged that

it would have been obvious to modify Mallik to be a volume hologram because volume holograms are well-known and volume holograms have better defraction efficiency.

Applicant respectfully asserts that such statements are improper because there is a fundamental difference between the surface relief hologram as described in Mallik and a volume hologram. Applicant provides the following explanation as to why one of ordinary skill in the art would not simply convert the teachings of Mallik to include a volume hologram.

Differences between Volume Hologram and Embossed Hologram and why one skilled in the art would not regard them as interchangeable structures.

1. Surface relief phase (embossed holograms)

Embossed surface relief holograms (or DOVIDS) are without question the most common form of security hologram – this prevalence being largely driven by the very low costs associated with using the technique of embossing as a means of mass manufacture. Surface relief holograms function by the process of diffraction which in more fundamental terms may be thought of as the process of interference by wave-front division. This wave-front division occurs when the incident wave front impinges on and is coherently scattered by the periodic relief pattern, with each individual peak and trough within the periodic relief acting as a secondary scattering source dividing and modifying the phase of the wave-front at each point on the relief by an amount determined by the relief amplitude.

Figure 1 shows in very fundamental terms how a surface relief hologram may be recorded. The object beam is a diverging light source emanating from a point like source while the reference beam is a collimated wave front. Both impinge on the recording material (photo-resist) from the same side to generate a holographic interference pattern - a periodic pattern of bright and dark fringes (interference maxima and minima respectively). The

interference maxima are shown in Figure 1 as broken lines. The spacing **s** between the interference maxima being equal to $\lambda / 2\sin\theta$ where θ is the half angle between the object and the reference beam and λ is the wavelength of the incident light. How these fringes modify the resist layer following processing depends on whether the resist is positive or negative working – assuming its is positive then the interference maxima will act to preferably dissolve or etch the resist layer as shown in **figure 2** to create an undulating periodic surface relief (sinusoidal in the simplest scenarios). The periodicity (distance between successive peaks) $d = \lambda / (2\sin\theta \cos\theta) = \lambda / (\sin 2\theta)$.

Fig 1
Recording a surface relief hologram into photo-resist

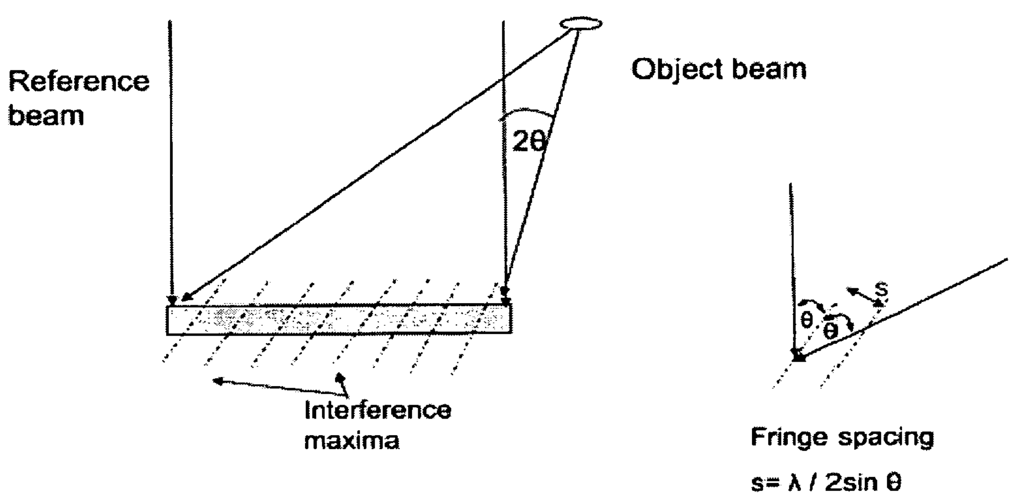
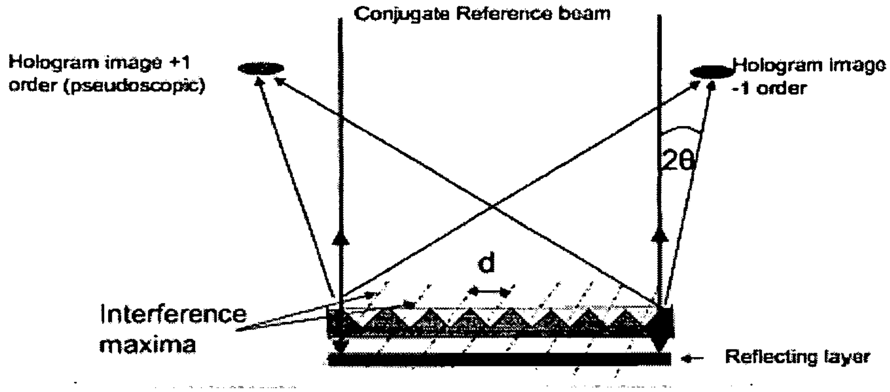


Fig 2

Reconstruction of surface relief (embossed) hologram using recording wavelength.



Grating pitch d = λ/ (2sinθ cosθ)

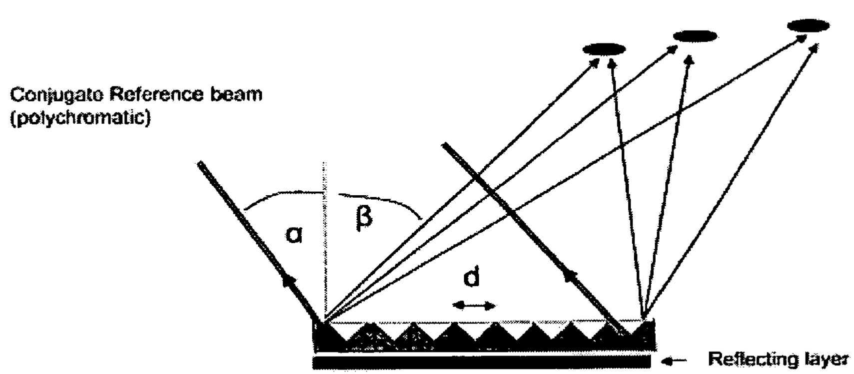
When this relief is illuminated by a conjugate reference beam it generates two images corresponding to the -1 and +1 orders, wherein the former image is located in the location of the original object source (the orthoscopic image) while the latter image is reconstructed on the opposing side of the reference beam and is known as the pseudoscopic image. This is the image you would see if you were to invert (180° rotation about viewing axis) a conventional embossed hologram. Surface plane image components would remain unchanged in the pseudoscopic, however elements visualized behind the surface plane in the orthoscopic image would appear in front of the surface plane in the pseudoscopic image and vice versa (i.e. there is a reversal of parallax effect between the two views).

Let us consider next the behavior of the embossed hologram or DOVID under polychromatic or white light illumination – this is illustrated schematically in **figure 3** wherein for simplicity we have chosen to omit the pseudoscopic order. Now the relationship governing angles of incidence **α**, diffraction **β**, grating periodicity **and** wavelength is the well

known diffraction equation **d (sinα-sinβ) = pλ** where p = the order of diffraction which in this case = -1. The key point is that for a given wavelength and grating periodicity the angles of incidence and diffraction are not constrained to singular values except in the special case **α = β.** Consequently we have the situation shown in figure 3 wherein rays of white light are incident at some angle which is not required to be the conjugate of the original reference beam. The effect of the grating structure is to diffract and disperse this polychromatic light into a spectrum of images (for clarity we show only the red, green and blue).

Fig 3

Illumination of embossed hologram with polychromatic light



General diffraction condition for surface relief hologram

d (sinα-sinβ) = λ When viewed in -1 order

What does this mean for an observer looking at a security hologram in white light?

Suppose the hologram image is comprised of a 3D globe wherein continents, oceans and features where recorded with different grating pitches or relative colors. The first thing

that the observer would notice is that at most angles of tilt vertical (within the plane of diffraction) at least some components of the globe would be visible in a particular rainbow color. The observer would further notice that as the hologram is tilted away from the observer the all colors would shift towards the blue end of spectrum (i.e. green changes to blue, red change to green etc.) Conversely, if the hologram is tilted towards the observer then the colors will shift towards the red end of the image. The observer might conclude the embossed hologram is not angularly selective as regards viewing geometry and it is suitable for providing polychromatic images with the same spectral range and content as the illuminating light and further more this polychromatic image is optically variable upon tilting. Further to this should the observer view the hologram under both directional (point source) lighting and diffusing (extended / multiple source) lighting, then he/she will notice the 3D globe to appear sharp and well defined under directional illumination while conversely the globe will appear significantly more smeared or blurred under diffused lighting. The observer will correctly conclude that while an embossed hologram is an effective device for viewing multi-colored 2D and quasi 2D images under most lighting conditions, it has significant limitations as a holographic vehicle for 3D images under diffuse lighting conditions. Finally on inverting the hologram he will notice the globe image to remain visible but will have the psycho-optically disturbing property of appearing *inside-out!*

Industrial Manufacture of Embossed Holograms

What we have so far described is the process of recording a very simple embossed hologram in resist and then describing its subsequent replay characteristics when combined with a reflection coating. The resist hologram is the first or master hologram original hologram from which all subsequent copies are derived and the process of creating it is

usually referred to as the origination process (creation of the original hologram) and needs to be distinguished from the industrial process of generating hundreds, thousands and millions of hologram copies for use as security devices. The latter is usually thought of as the manufacturing process and central to it is the mechanical process of embossing or impressing the hologram relief structures into webs of thermo-plastic coated Polyester. The process starts with generating a Nickel copy of the resist master or origination via the galvanic process (electroplating). This galvanic process is repeated growing alternatively positive, negative, positive... thus synthesizing a pyramid of copies such that several tens of identical positive nickel copies are available (embossing shims) to be secured to a die roller. In a web to web process the hologram foil is then fed through a heated pressurized nip comprising the die roller and a compression roller. Following the process of embossing the hologram foil is then coated with a reflection enhancing film – typically Aluminum if an opaque reflector is required and ZnS if a transparent reflector is required.

2. Volume Holograms

Volume holograms or what might alternatively be referred to as a thick reflection hologram differs fundamentally from an embossed surface relief hologram in that while both are recorded by the process of holographic interference process, a volume hologram reconstructs its image through the effect of Bragg reflection (interference by amplitude division) while an embossed hologram reconstructs light by the process of diffraction (i.e. interference by wave-front division). Also the method of mass replication or manufacture for the two structures is radically different.

Figure 4 shows schematically the recording of a volume hologram wherein the object is a point like source of light while the reference beam is plane wave. The object and

reference beam illuminate the recording material (and supporting substrate not shown) from opposite sides such that they create fringes of constructive and destructive interference. The fringes or loci of constructive interference are shown as broken dotted lines within figure 4 – the spacing of these fringes (i.e. interference maxima) is given by the relationship

$$da = \lambda a / 2n\sin\varphi.$$

Generally the effect of the interference maxima is to create, after suitable processing, localized elevations of refractive index relative to the medium average – in other words via processing the interference maxima map / convert into planes of higher refractive index (index steps) each having the capacity to partially reflect a small percentage of the incident amplitude.

Fig 4

Recording a volume hologram

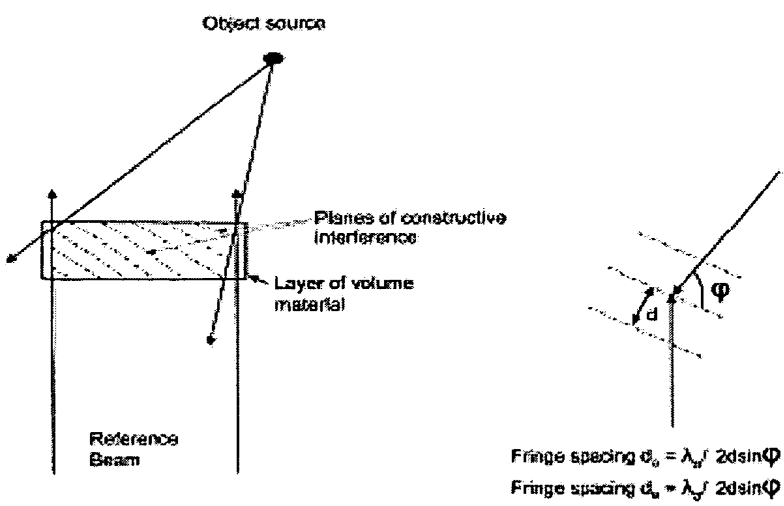
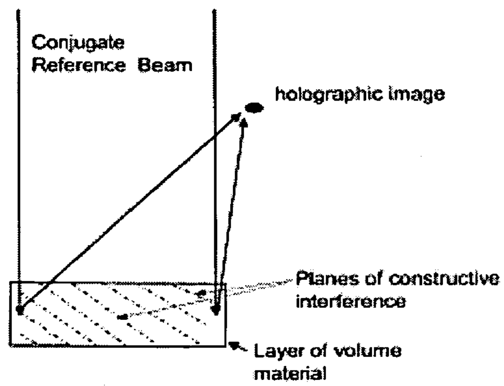
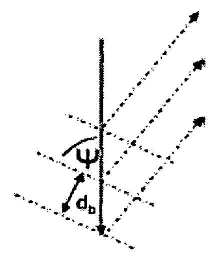


Figure 5 shows how the processed volume hologram reconstructs an image of the original object when illuminated by a true conjugate reference beam. The optical conjugate of a light beam is one which has the **same wavelength and wave front characteristics** as the original recording beam and differs only in having a reversed wave-vector, *i.e.* propagates in exactly the reverse direction of the original recording beam.

Fig 5

Reconstruction of a volume hologram





Note if there is no fringe shrinkage i.e $d_a = d_b$ then for a thick volume hologram reconstruction wavelegth and reconstruction angle must match the original recording geometry.

On the right hand side of figure 5 we see in more detail how the image is reconstructed by reflection within the medium. We can see that as the conjugate reference beam propagates through the medium, then at each plane of elevated refractive index a fraction of the incident light is reflected (a partial reflection of the incident amplitude); however, within a typical volume hologram the number of reflective planes will be typically at least of multiples of tens and more usually will be quantified in the 100s or 1000's. For a bright image to be formed it is necessary that all these partial reflections combine in phase. This occurs when the wavelength and angle of incidence relative to the partial planes satisfies the Bragg condition

$$2n\, d_b \sin\Psi = \lambda b$$

It should be clear from a comparison of this expression with the preceding one for fringe spacing, that if the recording and reconstruction wavelengths are the same and there is no shrinkage of the volume material during processing, then only light incident on the volume

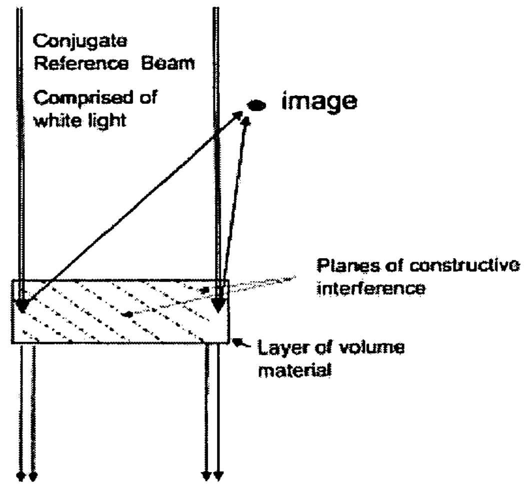
hologram at the same angle as the original recording reference beam will get Bragg reflected to form an image. It can also be seen from figures 1 & 2 that a divergent / convergent object beam will create interference fringes and thus refractive index planes whose angle of tilt will vary across the plane of the recording material. Hence the reflection angle Ψ will vary locally across the plate. **It then follows that the Bragg condition can only be simultaneously for all local values of Ψ if both the wavelength and angle of incidence of the reconstruction beam matches that of the original recording reference beam.** Finally we should note that the volume hologram operates not by diffraction but by the process of interference between light amplitudes derived from multiple partial reflections. Hence a volume hologram may be more pertinently described as a Bragg reflection hologram.

What does this angular and wavelength selectivity of a volume hologram mean for every day polychromatic illumination. ?

Consider **figure 6** which shows the volume hologram illuminated by a reference beam which in angular terms is a conjugate of the original reference beam - however this time it differs from the original recording beam in being polychromatic (i.e. white light). Now only a band of wavelengths close to the original recording wavelength will satisfy the condition for Bragg reflection and thus form the image reconstructing wave-front. Suppose the original recording laser / wavelength is green, then it follows that only a green hologram image will be formed, whereas the red and blue parts of the spectrum will be transmitted. Note if processing the volume hologram post exposure causes the material to swell, this will increase the fringe spacing d_b and thus drive the condition for Bragg reflection towards a longer wave-length (i.e. red shift) whereas material shrinkage during processing will reduce d_b and thus drive the condition for Bragg reflection towards shorter wave lengths (i.e. blue shift).

Fig 6

Volume hologram illuminated with polychromatic (white) light



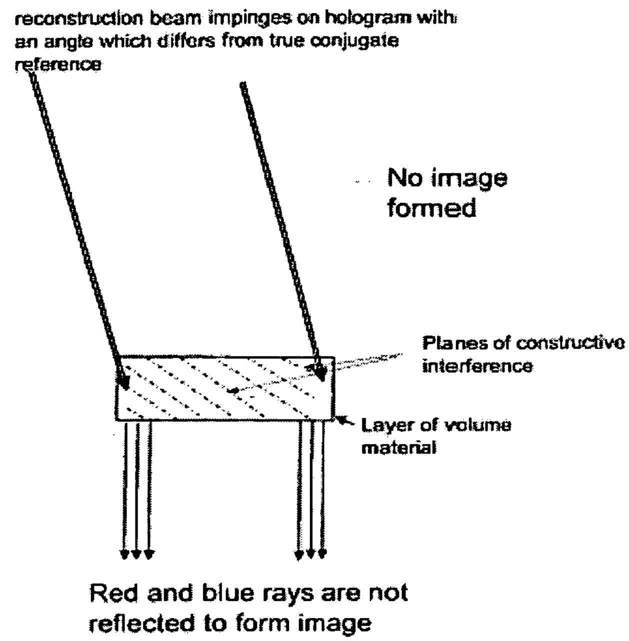
Red and blue rays are not reflected to form image

Hence in poly-chromatic or white light illumination, the volume hologram is wavelength selective and replays an image of a specific color. In practice most typically green matching the 514nm line of the Argon ion laser. Volume holograms in practice are applied with or to a black background to absorb the transmitted light.

Let us consider now the situation wherein the polychromatic light source used to reconstruct the hologram is no longer incident at the same angle as the original recording reference beam as shown in **figure 7**. In this scenario, none of the incident wavelengths can satisfy the Bragg reflection condition and all of the light is transmitted and no hologram image is formed. Therefore should a volume hologram be illuminated by light from multiple light sources then it will select only those rays which match the original recording geometry in reconstructing the image.

Fig 7

Illumination of volume hologram with a non conjugate reference



Given the above, what will be the visual experience of viewing a single layer volume hologram?

To begin with suppose the volume hologram contains an image of a 3D model such as a globe. First, the observer will notice that only when the hologram is held at a particular angle of tilt within the plane of reflection is an image visible – this angle satisfying the Bragg condition. Second, this image of the globe will appear with a particular color or chroma (usually green). Third, the observer would notice that in contrast to an embossed hologram, the hologram image had a very similar appearance when viewed in both directional (i.e point source) and diffuse illumination – this contrasts with an embossed hologram wherein the 3D image would appear strongly smeared or diffused when viewed under diffuse lighting. Finally, the observer would notice than when the hologram was inverted (i.e. rotated by 180

degrees about the viewing axis) no image would be visible – again this contrasts with an embossed hologram wherein the pseudoscopic image would be visible.

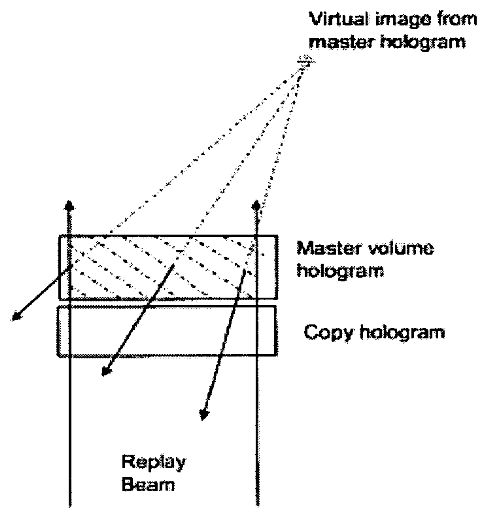
Industrial Manufacture of Volume Holograms

Now, because the microstructure within a volume hologram is in the form of periodic variations of refractive index within the medium, copies of a volume hologram cannot be generated by mechanical means. Instead in stark contrast to a surface relief hologram copies must be generated by optical means – specifically the process of optical contact copying shown schematically in **figure 8.** The replay beam not only reconstructs the object beam from master hologram but also provides the reference beam for the copy hologram thus matching the original wave front geometry and thus interference pattern of figure 4.
In practice a matrix of master holograms would be ganged up to act as an object source so as to contact copy a matrix of copy holograms in a single exposure process.

It should be appreciated that very few, if any, industrial organizations possess both the capability to manufacture embossed holograms and volume holograms and indeed hitherto they have been seen as mutually exclusive competing technologies. Hence there are few skilled practitioners who will be familiar with the optical characteristics of both technologies and will have considered the value or practical detail of combining them in one integrated optical security device.

Fig 8

Contact copying a volume hologram
hologram



However, it is precisely because these two classes hologram have such complimentary viewing characteristics and such fundamentally different manufacturing technologies that the combination of the technologies in one device serves to provide a uniquely secure and visually distinctive technology.

II. New Claims 104-131

Applicant respectfully asserts that claims 104-131 are patentable for at least the following reasons.

These claims relate to the embodiment in which there are two superposed surface relief microstructures. Importantly, a discontinuous metallic layer is provided in conjunction with the first microstructure <u>in register</u> with the microstructure. The significance of the term "in register" is that it means metal is provided in all regions where there is microstructure but not in regions where there is no microstructure. This means that the brightness of the first

holographic optically variable effect generating structure can be maintained but at the same time the underlying second structure is visible.

This should be contrasted with the invention of Mallik in which a regular array of spots 25 of reflective material is provided associated with the surface relief hologram 23. It can readily be seen in Mallik's Figure 11 that some regions of that hologram are not provided with the metallic spots 25 which means that the optimum replay brightness of that hologram is immediately reduced. It can be seen in Mallik's Figure 11 that about 50% of the surface of the hologram 23 is provided with metallic spots meaning that there will be a 50% reduction in brightness. On the other hand, with the invention, because the metallic layer is provided in register with the microstructure, the microstructure is fully covered by a metallic layer and full brightness is maintained. The underlying hologram in the invention is viewed through non-embossed regions of the layer provided in the first structure. This is not shown in the specification.

The independent claims also refer to the inclusion of a dye or pigment between the two optically variable effect generating structures. The Office Action acknowledged that this feature is not disclosed in Mallik (in reference to previous claim 48) but argues that it would be obvious in view of the use in Mallik of a printed photograph or writing. However, this printed photograph is not provided between two optically variable effect generating structures but simply on one surface of the substrate 11 (column 4, lines 29-32). There is certainly no suggestion or motivation to incorporate such printing or writing between the two optically variable effect generating structures described from column 9, line 35.

The use of such dyes and pigments enables very special optical effects to be generated in combination with the optical variable effect generating structures making the device very difficult to counterfeit but yet easy to authenticate.

In view of the foregoing, it is respectfully submitted that this application is in condition for allowance. Favorable reconsideration and prompt allowance is earnestly solicited.

Should the Examiner believe that anything further would be desirable in order to place this application in even better condition for allowance, the Examiner is invited to contact the undersigned at the telephone number set forth below.

Respectfully submitted,

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JAO:SDJ/hlp

Attachments:
Petition for Extension of Time
Amendment Transmittal

Date: February 26, 2009

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